# Male Astronauts Have Greater Bone Loss and Risk of Hip Fracture following Long Duration Spaceflights than Females

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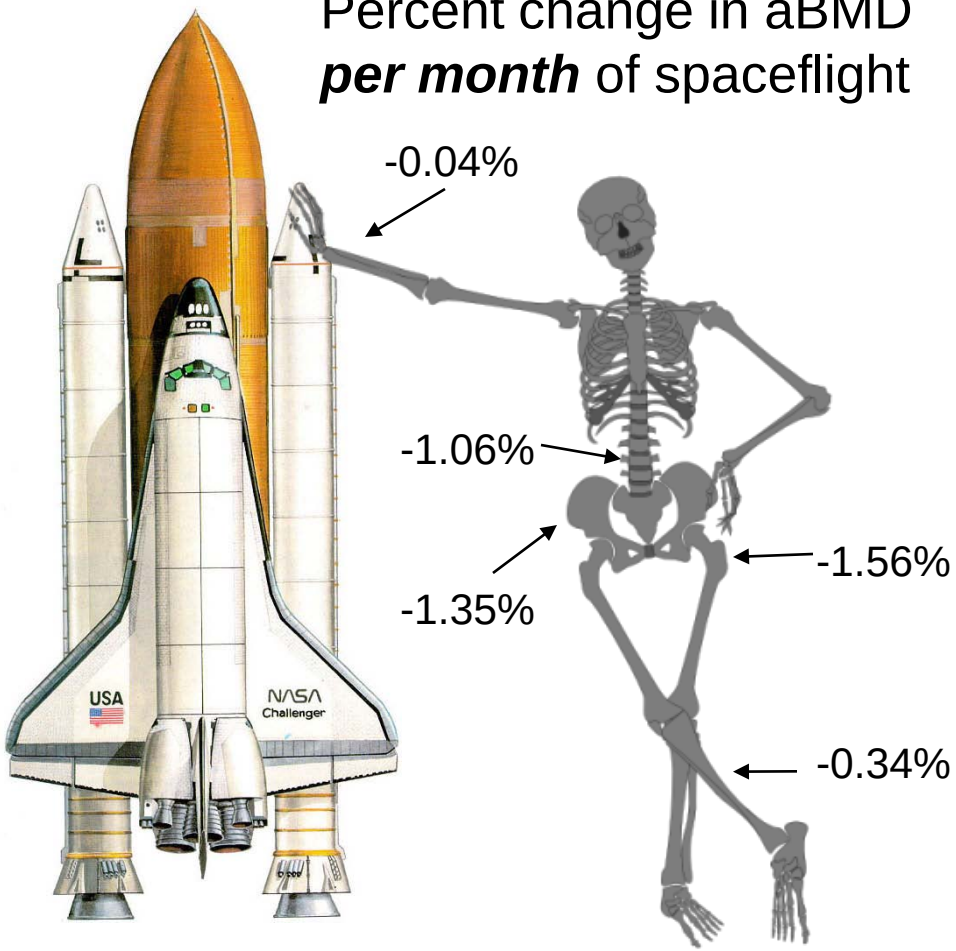
# Astronauts lose bone rapidly in microgravity

Percent change in aBMD ***per month*** of spaceflight

**vs**

Rate of bone loss in postmenopausal osteoporosis

-1 to 2%/***year***




*LeBlanc JMNI 2000*

# In-flight Countermeasures

- Exercise up to 2.5 hours/day (allotted time)
- Vitamin D supplementation

Treadmill (TVIS)

Cycle ergometer (CEVIS)

Resistance (IRED)

# Research Questions

1. Is there a sex-specific difference in microgravity induced bone loss?
2. Can factor-of-risk analysis be used to identify individuals at risk for hip fracture?
3. Do BMD and factor-of-risk recover to baseline levels after returning to Earth?

# Subjects

- All long duration NASA astronauts who completed missions on the ISS (2000 - May 2009)
  - 20 males (1 repeat)
  - 5 females (1 repeat)


| | **Women** | **Men** | |
|---|---|---|---|
| **Weight (kg)** | **67.5 ± 4.2** | **81.4 ± 8.5** | **p=0.002** |
| **Height (m)** | 1.69 ± 0.03 | 1.75 ± 0.07 | p=0.06 |
| **Age (years)** | 43 (41 to 47) | 46 (37 to 54) | NS |
| **Mission Length (days)** | 175 (134 to 195) | 170 (95 to 215) | NS |

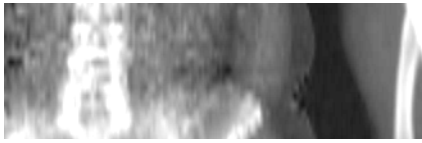
# Outcome assessments: aBMD

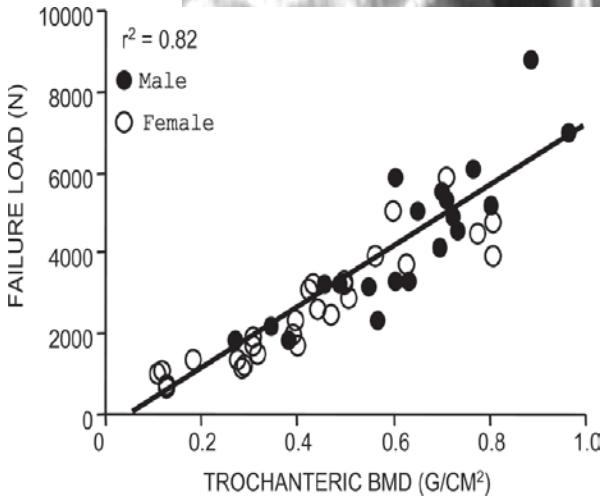
- Bone mineral density by DXA
  - Whole body and L hip
    - Preflight
      - 1 month to 1.5 years before flight
      - 80% within 6 months
    - Postflight
      - 5 to 32 days after landing
    - Follow up
      - Annually until “full” recovery, then triennially
      - 1 to 6 postflight scans per person

# Outcome assessments: Factor-of-Risk

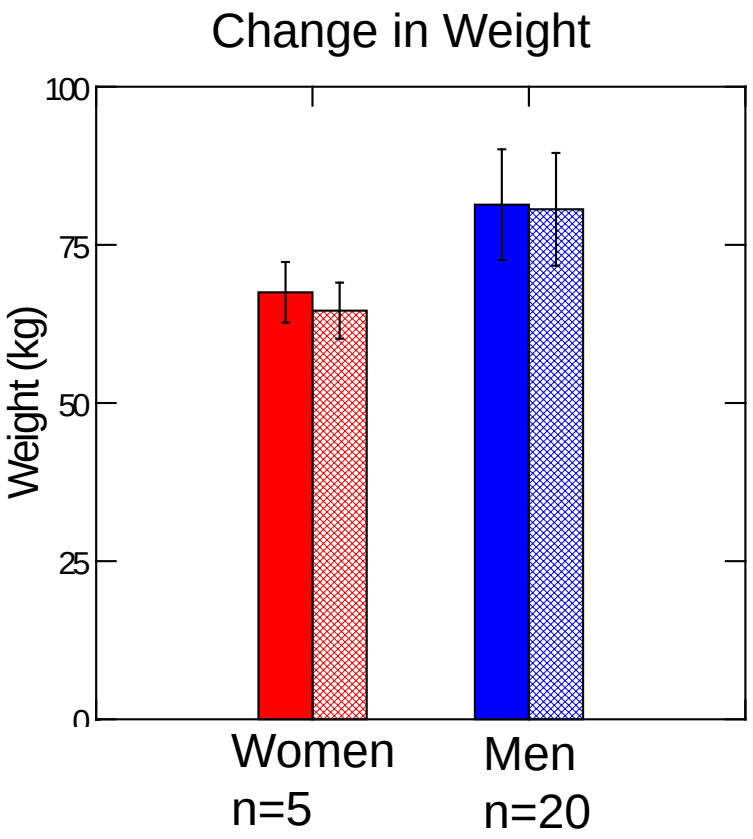
$$\text{Factor of Risk} = \frac{\text{Fall Force}}{\text{Bone Strength}}$$

- **Fall Force**: impact force due to sideways fall
  - Estimated from biomechanical model
  - Function of height, weight, soft tissue thickness
- **Bone strength**: failure strength of hip with sideways fall loading
  - Estimated from mechanical testing of cadaver femora
  - Function of aBMD

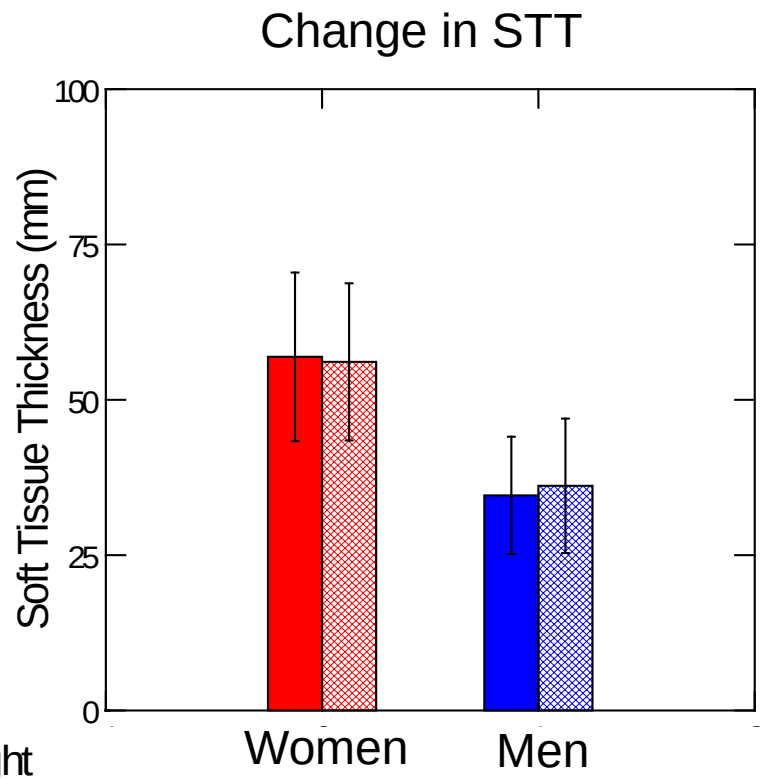




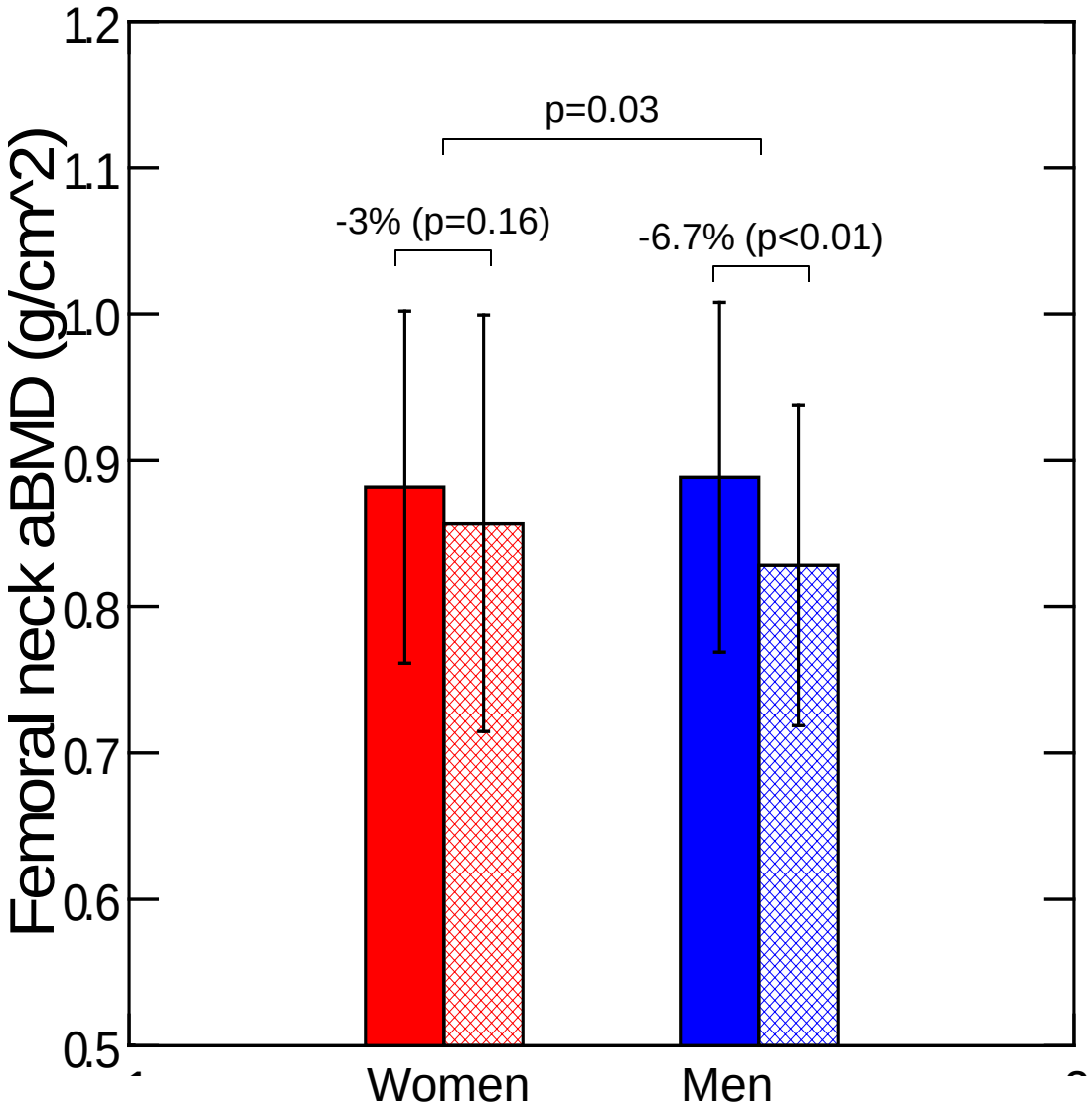
# Weight and soft tissue thickness do not change in flight







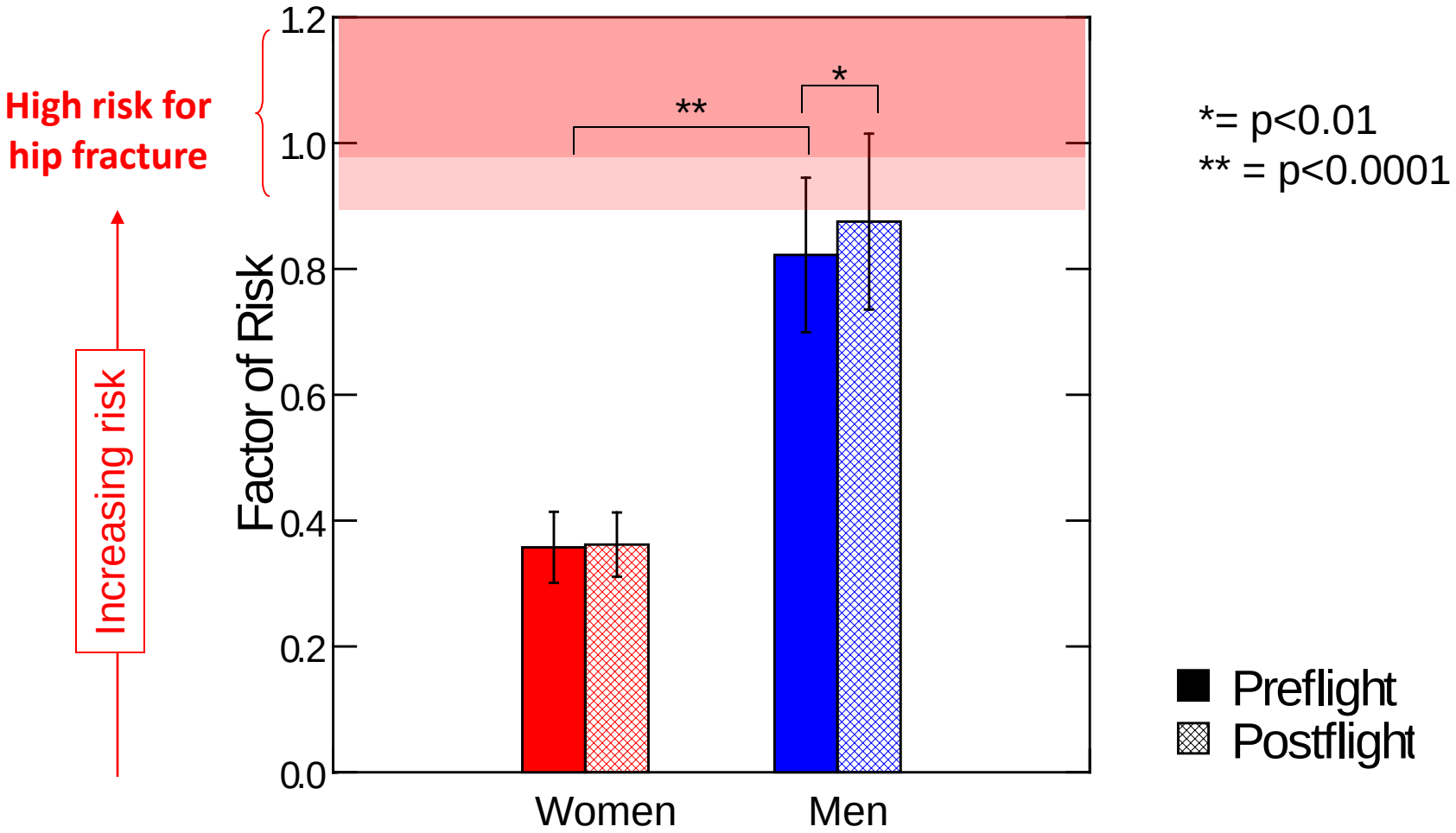
# Bone loss is greater in men than women



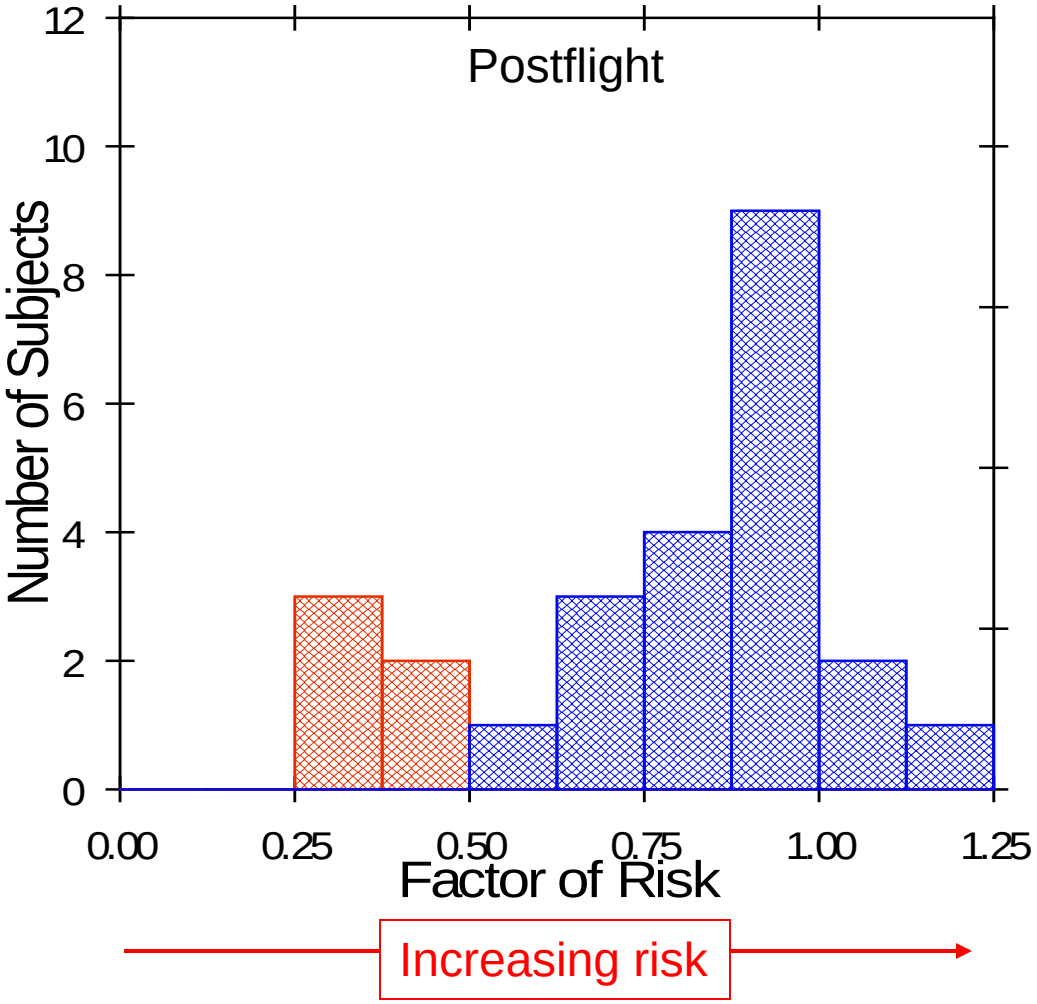

| | Monthly Rate $\left(\frac{g/cm^2}{month}\right)$ |
|---|---|
| Men | -1.30% |
| Women | -0.55% |

Preflight
Postflight

# Factor-of-risk is markedly higher in men and increases more postflight

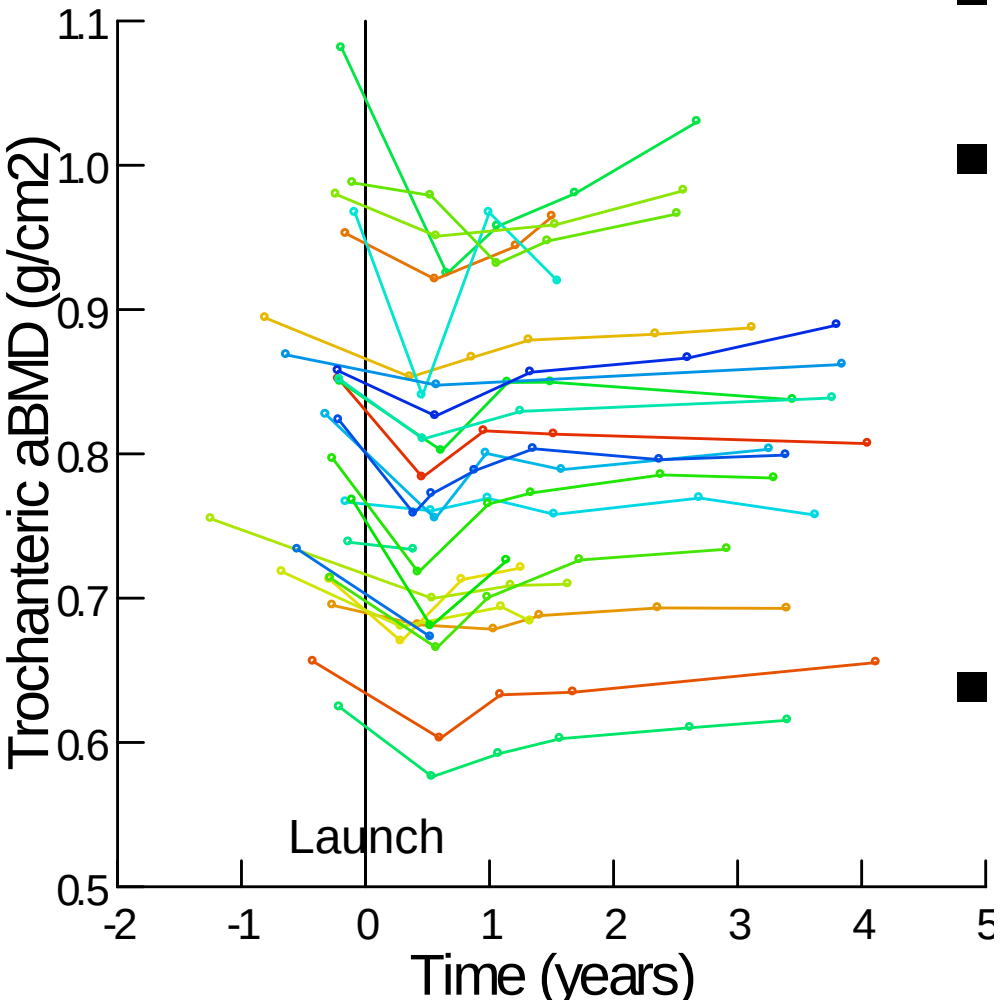


# Many male crewmembers are at high risk for hip fracture postflight




| | | High Risk for Fracture (Φ ≥ 0.9) |
|---|---|---|
| **Preflight** | **Men** | 5 (25%) |
| | **Women** | 0 |
| **Postflight** | **Men** | 11 (55%) |
| | **Women** | 0 |
| **Recovery** | **Men** | 5 (25%) |
| | **Women** | 0 |

# Recovery of bone is incomplete and variable




- Highly variable rate of bone loss and recovery
- Most recovery occurs within first 1.5 years postflight
  - Average slope = +0.038 g/cm$^2$/year
  - No significant change in aBMD after 1.5 years
- n of people who don't reach baseline BMD in 1.5 years

# Strengths and Limitations

- Strengths
  - Large data set of long-duration NASA astronauts
  - Accounts for other biomechanical factors leading to hip fracture
- Limitations
  - Femoral strength estimated from DXA aBMD measurement
  - Modeled for sideways fall only
  - Small sample set

# Conclusions

- Male astronauts experience a greater decrease in hip BMD than females after exposure to microgravity
- Men have a significantly higher factor-of-risk than women
  - Due to less soft tissue padding and greater height and weight
- Most recovery of BMD occurs within the first 1.5 years after return.
  - 5 male astronauts continue to be at high risk for hip fracture 3 years after return

# Why do men lose more than women?

- Possible explanations
  - Physiological
    - Estrogen is protective for pre-menopausal female crewmembers
  - Environmental
    - Men are stronger than women and max out the exercise equipment
      - iRED can only provide 135 kg of resistance

# Acknowledgements


- Lisa King (NASA JSC)
- Ben Roberts (BIDMC)

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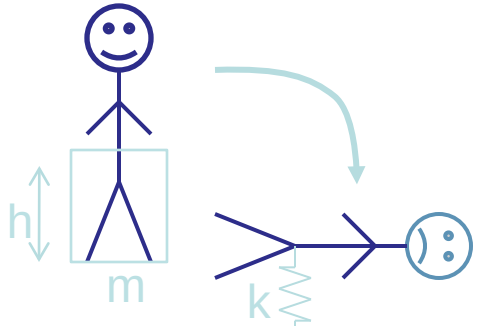
# Estimation of Fall Force




$$F_{atten} = \sqrt{2ghmk} - 71 * ST\ thickness$$

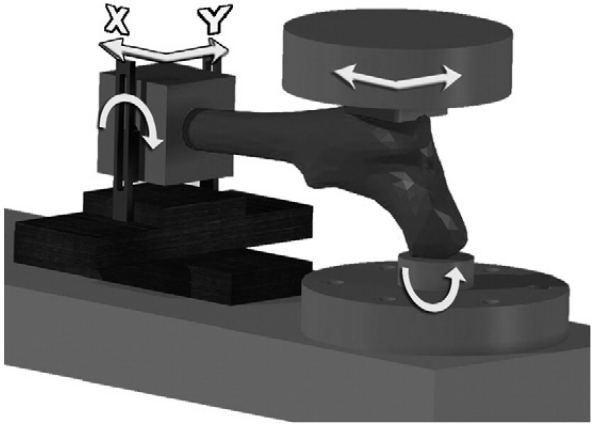
- g = 9.81 m/s$^2$
- h = height of c.g.
- m = effective mass
- k = stiffness constant

Soft tissue thickness

# Estimation of Femoral Strength

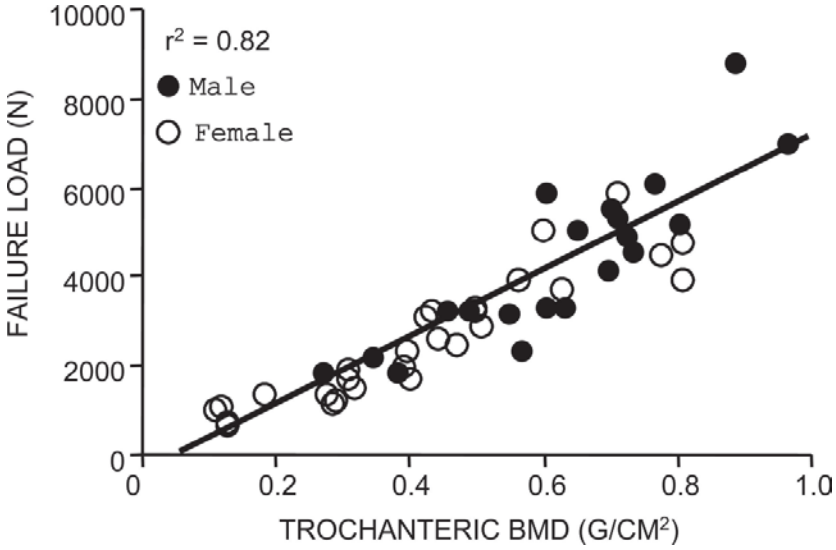
- Mechanical testing of cadaver femora to failure in sideways fall configuration

Roberts, Bone 2010




- Linear regression used to predict subjects' femoral strength

$$\text{Estimated Femoral Strength (N)} = 10118 \times \text{Troch aBMD (g/cm}^2\text{)} - 1512.5$$




Bouxsein, JBMR 2007